CORNING

OLED Encapsulation

Mark Taylor
Emerging Innovations Group

January 28, 2014
DoE Solid State Lighting R&D Workshop
Tampa, Florida

taylormp@corning.com

Introduction

- Objectives of today's remarks
- Encapsulation choices
- Edge sealing choices
- Application of frit sealing to OLED lighting
- Encapsulation research needs

Encapsulation targets

- Performance
  - Permeability* < $1x10^{-6}$ $g_{water}/m^2/day$
  - < $1x10^{-5}$ $g_{oxygen}/m^2/day$
- Cost
  - $\$10\text{-}20/m^{2*}$
- Reliability >40,000 hours active / 20 years lifetime
  - Damp heat degradation
  - Mechanical stress
  - Thermal stress

*DoE Manufacturing Roadmap - 2013

Encapsulation material choices

Material	Pro's	Con's
Metal can	• Low cost • Easy to pocket for desiccant	• Poor CTE match • Stamping costs • Edge seal required
"Thick" Glass (>0.2 mm)	• Excellent moisture, oxygen and thermal resistance • Low cost • Transparent • Expansion match to substrate	• Rigid • Pocket required for desiccant if frit seal is not used • Edge seal required
Polymer film	• Flexible	• High cost • Damage sensitivity • Edge seal required
Deposited coatings	• No edge seal	• High cost • Additional (complex) deposition step • Damage sensitivity • May require backup glass
"Thin" glass (<0.2 mm)	• Flexible/conformable • All other glass advantages	• Fragile and may require polymer backup • Flexible edge seal required with flexible substrate

Edge sealing technology options

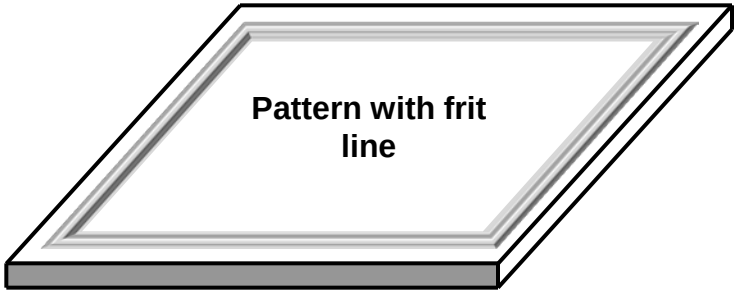
Technology	Pro's	Con's
Laser glass frit seal	• Established OLED sealing technology • Hermetic seal • Capable of sealing over electrical leads • Narrow seal band	• Multiple process steps • Expensive • Stress buildup with larger sizes • Anticlastic bending stress
Polymer seal	• Low temperature • Inexpensive process steps • Supports flexibility	• May degrade under aggressive environmental conditions • Not hermetic • Wide seal band • Requires desiccant • Best performing materials are expensive

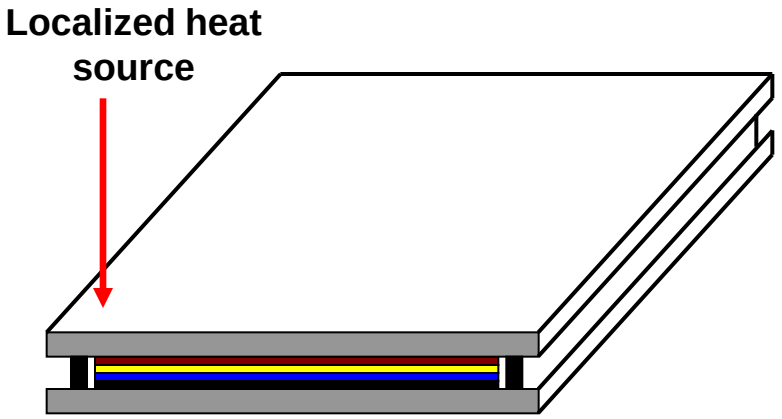
Corning developed a hermetic sealing solution using a low Tg glass frit

Deposit required width and thickness frit line on cover glass

Frit uniquely designed to absorb required energy

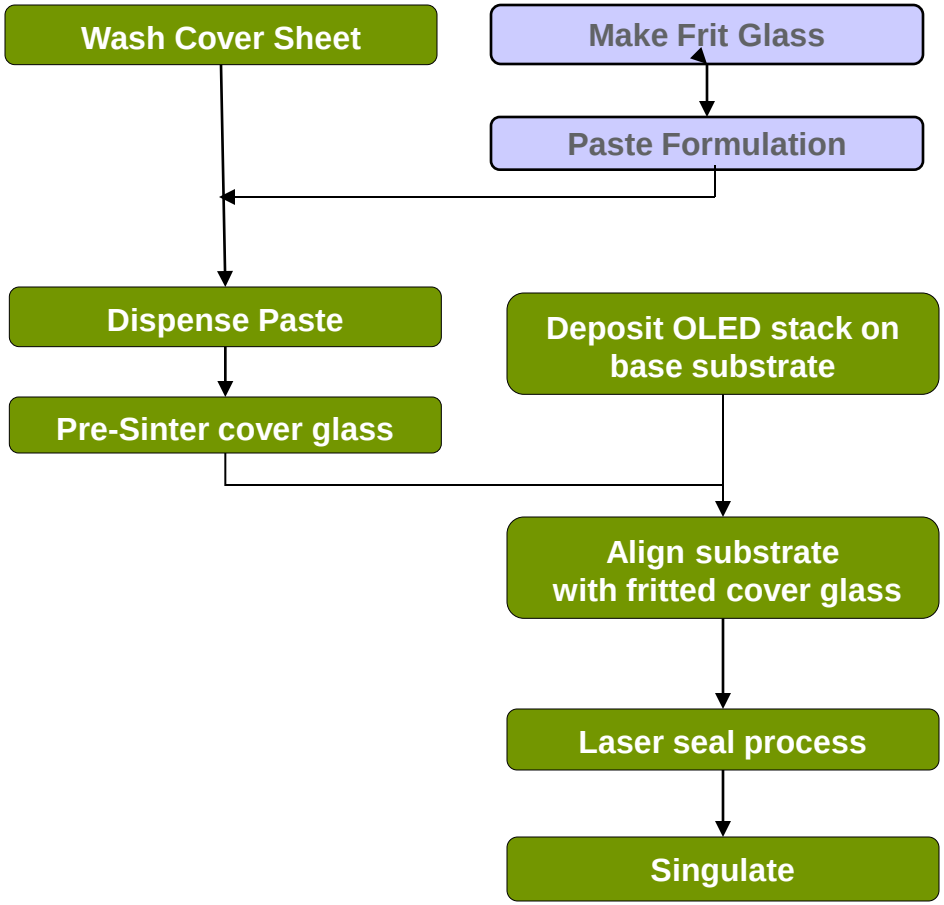
Align cover glass with backplane / OLED stack and seal with localized heat source





- ✓ **Developed a low Tg frit with unique absorption characteristics tuned to a specifics wavelength region (IR)**
- ✓ **Designed frit with a selective filler material to adjust the CTE**
- ✓ **These unique features offered sealing compatible with OLEDs**

OLED laser frit sealing process flow



Seal performance was demonstrated with different lead configurations and with live OLEDs

- Sealing tests performed successfully over various lead materials/passivation layers
  - Mo, W, Ti, Cr, ITO, multi-layer metals
  - SiN_x, SiO_2 passivation materials
- Sealing performance – sealed over lead material,
  - Ca test at 85C/85% RH passes 8,500 hrs with glass package
  - Successfully demonstrated over active and passive backplanes
- Successfully sealed many hundreds of live OLED samples without damage to leads or to the OLEDs
  - Sealing confirmed hermetic
  - No electrical issues with display performance
- AM OLED displays exceeded 2000 hours under 85C/85% RH testing

Technology wishlist

- Stress modeling of hermetically sealed glass laminate
- Reduced cost of sealing polymers
- Greater flexibility of polymers after curing
- Lower permeability to reduce desiccant load
- Solid state polymer encapsulant with inorganic layers and glass or polymer barrier

CORNING